The science behind the report:

Set up students and teachers to excel now and in the future with Intel processor-powered ChromeOS devices

This document describes what we tested, how we tested, and what we found. To learn how these facts translate into real-world benefits, read the report Set up students and teachers to excel now and in the future with Intel processor-powered ChromeOS devices.

We concluded our hands-on testing on December 21, 2023. During testing, we determined the appropriate hardware and software configurations and applied updates as they became available. The results in this report reflect configurations that we finalized on December 14, 2023 or earlier. Unavoidably, these configurations may not represent the latest versions available when this report appears.

Our results

To learn more about how we have calculated the wins in this report, go to http://facts.pt/calculating-and-highlighting-wins. Unless we state otherwise, we have followed the rules and principles we outline in that document.

Table 1: Results of our testing.

Lenovo IdeaPad® Slim 3i Chromebook™ with an Intel® Core™ i3-N305 processor	Lenovo 14e Chromebook Gen 3 with an Intel Processor N200	Lenovo 14e Chromebook Gen 3 with an Intel Processor N100	HP Chromebook x360 with an Intel Celeron® N4500 processor
Traditional session-restore scenario (lower is better, mm:ss)			
1:54	2:20	2:43	3:26
Session restore scenario featuring AI (lower is better, mm:ss)			
2:21	2:41	2:56	3:59

This project was commissioned by Intel.

System configuration information

Table 2: Detailed information on the systems we tested.

System configuration information	Lenovo 14e Chromebook Gen 3	Lenovo 14e Chromebook Gen 3	Lenovo IdeaPad Slim 3i Chromebook	HP Chromebook x360
Processor				
Vendor	Intel	Intel	Intel	Intel
Model number	N100	N200	Core i3-N305	Celeron N4500
Core frequency (GHz)	1.0 – 3.4	1.0 – 3.7	1.8 – 3.8	1.1 – 2.8
Number of cores	4	4	8	2
Cache (MB)	6	6	6	4
Memory				
Amount (GB)	4	8	8	4
Type	DDR5	DDR5	DDR5	DDR4
Speed	4,800	4,800	4,800	2,933
Storage				
Amount (GB)	32	128	128	32
Type	eMMC	eMMC	eMMC	eMMC
Connectivity/expansion				
Wireless internet	Wi-Fi 6E AX211	Wi-Fi 6E AX211	Wi-Fi 6E AX211	802.11 AC
Bluetooth	5.1	5.1	5.1	5
USB	2x USB 3.2, 1x USB-C® 3.2	2x USB 3.2, 1x USB-C 3.2	2x USB 3.2, 1x USB-C 3.2	2x USB-C, 1 USB Type-A
Video	HDMI® 1.4	HDMI 1.4	HDMI 1.4	N/A
Battery				
Type	Lithium polymer	Lithium polymer	Lithium polymer	Lithium-ion
Size (WHr)	57	57	57	47
Display				
Size (in.)	14	14	14	14
Type	IPS	IPS	IPS	TN
Resolution	1920x1080	1920x1080	1920x1080	1366x768
Touchscreen	Yes	Yes	Yes	Yes
Operating system				
Build number or version	ChromeOS™ 119.0.6045.212	ChromeOS 119.0.6045.212	ChromeOS 119.0.6045.212	ChromeOS 119.0.6045.212
Dimensions				
Height (in.)	0.67	0.67	0.76	0.73
Width (in.)	12.77	12.77	12.77	12.85
Depth (in.)	8.51	8.51	8.51	8.65
Weight (lbs.)	3.2	3.2	3.3	3.5

How we tested

Setting up the systems

The goal of our testing was to demonstrate the time it takes for a Chromebook to restore from a previous OS session. Before testing, we set the systems up by first resetting each system and updating to the latest available version of ChromeOS. We then enrolled each Chromebook to a Google Workspace™ Business domain using Enterprise Enrollment. We downloaded the learning games Kahoot! and Squid from the Google Play™ store and created test accounts. We also downloaded two publicly available economics textbooks in PDF format, and placed them both in the local downloads folder of the devices, as well as their Google Drive™ storage. We then opened Chrome and opened each of the web pages we list below. Where necessary, we created test accounts and populated the web apps with material suitable for an Economics 101 online classroom environment.

- https://classroom.google.com with an example Economics 101 assignment loaded
- https://drive.google.com viewing the Economics Classroom folder
- https://drive.google.com viewing the device's personal folder
- https://slidesgo.com/theme/ab-testing-infographics
- https://docs.google.com viewing the A/B Testing Infographic Google Slides™ presentation above
- https://jamboard.google.com viewing an example economics Jamboard™
- https://docs.google.com viewing an economics textbook
- https://bard.google.com/chat
- https://en.wikipedia.org/wiki/Economics
- https://espn.com
- chrome://diagnostics

With each webpage loaded, we then navigated to the desktop and opened the downloads folder. We opened the two textbook PDF files using the default ChromeOS Gallery viewer. We then opened the default Google Play Store applications for Gmail, Calendar, and YouTube. We opened the YouTube app to begin playing an educational Economics 101 video. We opened the previously downloaded Squid app and opened our test Squid Note. We then opened Kahoot!, closed any pop ups, and clicked the Join button. Finally, we ensured the Chrome Diagnostics window was open on top of all other apps and tabs.

Restoring apps and tabs from a previous session for the traditional session-restore scenario

1. Ensure you've loaded and opened each webpage and application in the correct order we specify above.
2. To force the system to shut down, hold the power button.
3. Wait for the system to shut down completely.
4. To reboot the device, press the power button.
5. When prompted, log in.
6. When the system asks if you want to restore apps and continue from where you left off, start the timer and click Restore.
7. Bring each of the following Google Play Store applications to the foreground by clicking their respective icon from the taskbar in the order listed below. As soon as the app is brought to the foreground, move to the next app:
   a. Gmail
   b. Google Calendar
   c. YouTube
   d. Squid
   e. Gallery Viewer (first PDF opened)
   f. Gallery Viewer (second PDF opened)
   g. Kahoot!
8. After each of the applications listed above has been invoked, open Google Chrome. The first tab to load will be classroom.google.com; wait for the tab to fully load.
9. To navigate to the next tab, press CTRL + Tab, and wait for the first drive.google.com tab to fully load.
10. To navigate to the next tab, press CTRL + Tab, and wait for the second drive.google.com tab to fully load.
11. To navigate to the next tab, press CTRL + Tab, and wait for the slidesgo.com/them/ab-testing-infographics tab to fully load.
12. To navigate to the next tab, press CTRL + Tab, and wait for the Google Slides tab to fully load.
13. To navigate to the next tab, press CTRL + Tab, and wait for the Jamboard tab to fully load.
14. To navigate to the next tab, press CTRL + Tab, and wait for the economics textbook tab to fully load.
15. To navigate to the next tab, press CTRL + Tab, and wait for bard.google.com/chat to fully load.
16. To navigate to the next tab, press CTRL + Tab, and wait for the Wikipedia tab to fully load.

17. To navigate to the next tab, press CTRL + Tab, and wait for ESPN.com to fully load.
18. When all tabs have fully loaded, open the Gmail application from the taskbar and ensure the application has fully loaded.
19. Open Google Calendar from the taskbar, and ensure the application has fully loaded.
20. Open YouTube from the taskbar and ensure that video playback has begun.
21. Open Squid from the taskbar and ensure the application has fully loaded.
22. Open the first Gallery Viewer and wait for the annotation feature to be useable.
23. Open the second Gallery Viewer and wait for the annotation feature to be useable.
24. Open Kahoot! And stop the timer when PIN input is registered.
25. Before recording the next result, restart the video at 0:00, navigate back to the first tab, and ensure the order of applications open matches the setup instructions.
26. Repeat steps 1 through 25 two more times, and record the median result.

Restoring apps and tabs from a previous session for the session-restore scenario featuring AI

For the following test, we used the same setup instructions we listed above, but included one additional open Google Chrome tab. We first created a test Google Meet™ meeting from a host computer and retrieved the invite link. On the system under test, we navigated to https://www.meet.google.com, entered the meeting code, and clicked Join. We ensured the device permissions allowed microphone and camera access, and clicked the Apply Visual Effects button. We chose the Blur Background (strongest option) visual effect and then closed the Apply Visual Effects window. We then performed the same test again, but included the meet.google.com tab.

1. Ensure you've loaded and opened each webpage and application in the correct order we specify above.
2. To force the system to shut down, hold the power button.
3. Wait for the system to shut down completely.
4. To reboot the device, press the power button.
5. When prompted, log in.
6. When the system asks if you want to restore apps and continue from where you left off, start the timer and click Restore.
7. Bring each of the following Google Play Store applications to the foreground by clicking their respective icon from the taskbar in the order listed below. As soon as the app is brought to the foreground, move to the next app:

   a. Gmail
   b. Google Calendar
   c. YouTube
   d. Squid
   e. Gallery Viewer (first PDF opened)
   f. Gallery Viewer (second PDF opened)
   g. Kahoot!

8. After each of the applications listed above has been invoked, open Google Chrome. The first tab to load will be classroom.google.com; wait for the tab to fully load.
9. To navigate to the next tab, press CTRL + Tab, and wait for the first drive.google.com tab to fully load.
10. To navigate to the next tab, press CTRL + Tab, and wait for the second drive.google.com tab to fully load.
11. To navigate to the next tab, press CTRL + Tab, and wait for the slidesgo.com/them/ab-testing-infographics tab to fully load.
12. To navigate to the next tab, press CTRL + Tab, and wait for the Google Slides tab to fully load.
13. To navigate to the next tab, press CTRL + Tab, and wait for the Jamboard tab to fully load.
14. To navigate to the next tab, press CTRL + Tab, and wait for the economics textbook tab to fully load.
15. To navigate to the next tab, press CTRL + Tab, and wait for bard.google.com/chat to fully load.
16. To navigate to the next tab, press CTRL + Tab, and wait for the Wikipedia tab to fully load.
17. To navigate to the next tab, press CTRL + Tab, and wait for ESPN.com to fully load.
18. Navigate back to the meet.google.com tab to keep the webcam preview with background blur applied loaded.
19. When all tabs have fully loaded, open the Gmail application from the taskbar and ensure the application has fully loaded.
20. Open Google Calendar from the taskbar, and ensure the application has fully loaded.
21. Open YouTube from the taskbar and ensure that video playback has begun.
22. Open Squid from the taskbar and ensure the application has fully loaded.
23. Open the first Gallery Viewer and wait for the annotation feature to be useable.
24. Open the second Gallery Viewer and wait for the annotation feature to be useable.
25. Open Kahoot! And stop the timer when PIN input is registered.
26. Before recording the next result, restart the video at 0:00, navigate back to the first tab, and ensure the order of applications open matches the setup instructions.
27. Repeat steps 1 through 26 two more times, and record the median result.

This project was commissioned by Intel.